Assessing the Predictive Power of Labor-Market Indicators of Inflation

Farrokh Nourzad
Economics Department
Marquette University
P.O Box 1881
Milwaukee, WI 53201-1881
farrokh.nourzad@mu.edu

*This research has been financed in part by a grant from the Center for Global and Economic Studies at Marquette University.

**A short version of this paper is forthcoming in *Applied Economics Letters*.

Assessing the Predictive Power of
Labor-Market Indicators of Inflation

Abstract: This paper examines two different measures of wages as predicators of prices in a vector error-correction framework using quarterly data for the U.S. for the period from 1947.Q1 through 2008.Q1. Based on cointegration and a series of exogeneity tests, it is found that: 1) there is a stable, long-run relationship between the Consumer Price Index (CPI) and the Personal Consumption Expenditure Deflator (PCED) on the one hand and unit labor costs (ULC) and average earnings per unit of output (AHE) on the other; 2) ULC is weakly exogenous for both price indices while the two price indices are weakly exogenous for AHE; 3) ULC is strongly exogenous for CPI but not for AHE; 4) ULC is super exogenous for CPI. Taken together, these findings lead to the conclusion that ULC is a reliable indicator of price inflation but productivity-adjusted hourly earnings is not. Thus monetary policymakers are justified in using information about the behavior of ULC in formulating policy actions for achieving the goal of price stability.

JEL classifications are: C32; C52; E31.

Keywords are: Unit Labor Cost; Cointegration; Vector Error Correction; Exogeneity.

Assessing the Predictive Power of Labor-Market Indicators of Inflation

"The growth of unit labour costs accelerated in most developed countries during the first three months of this year, adding to central bank concerns that rising pay demands could fuel inflationary pressures." Financial Times, August 19, 2008, Page 4.

1. Introduction

Over the years central banks have used a number of different indicators of inflationary pressure on consumer prices including the money growth rate, exchange rates, the unemployment gap, the GDP gap, unit labor cost, and the employment cost index. The relationship between these indicators and the rate of price inflation has been studied extensively (Clark 1998; Ghali 1999; Gordon 1998; Hess and Schweizer 2000; Huh and Trehan 1995; Mehra, 1993, 2000; Rissman 1995).

Of the indicators mentioned above, wage growth has arguably received the most attention. Much of the work on the relationship between wage growth and price inflation is concerned with the markup pricing hypothesis, which would be supported by data if wage growth is found to predict price inflation. The common approach for testing this hypothesis is to use cointegration tests and the associated vector error-correction (VEC) models to examine both the long-run equilibrium relationship between the *levels* of wages and prices as well as the short-run relationship between the *growth rates* of these variables. This literature deals with the following issues:

- *Is there a long-run relation between productivity-adjusted wages and prices?*
- *Are wages exogenous to the parameters of the long-run relation if one does exist?*
- *Does causality run from wage growth to price inflation or the other way around? Or is there a bidirectional causality (feedback) between these two variables?*
- *Is the relationship between prices and wages stable over time?*

The first issue is typically answered in terms of cointegration tests, and the consensus appears to be that prices and wages are indeed cointegrated (Ghali 1999; Gordon 1989; Mehra 1993, 2000).[1] The second issue is examined by testing for weak exogeneity of wages and prices. The third issue is handled through Granger non-causality tests, where the findings are generally mixed ranging from wages Granger causing prices (Ghali 1999; Hess 1999; Mehra 2000), to prices causing wages (Hess 1999; Hess and Schweitzer 2000; Mehra 2000, 1993), to there being bidirectional causality between the two variables (Hess 1999; Mehra 1993), and to absence of a causal relationship in the Granger sense between prices and wages (Hess and Schweitzer 2000). This diversity of findings may be due to: 1) differences in the measures of prices, which include the fixed-weight GDP deflator, personal consumption expenditure deflator, chain-weighted GDP deflator; implicit GDP deflator, and the CPI; 2) the use of different measures of wages such as unit labor cost, hourly compensation, and average hourly earnings; and 3) differences in the periods of study.

[1] Several different cointegration tests have been used ranging from the traditional two-step Engle-Granger (1987) test to the more recent Johansen ML test (1988) and the Stock and Watson (1993) test based in Dynamic OLS models.

While most of the previous work has been concerned chiefly with the markup pricing hypothesis, the present study focuses on the performance of two labor-market variables as indicators of price inflation. For an indicator to be a good policy guide, it must satisfy several properties. First, there must be a stable, long-run relationship between the indicator and the policy goal variable, i.e., the two variables should be cointegrated. Second, in the long run, the target variable should follow movements of the indicator and not the other way around, i.e., the indicator should be weakly exogenous. Third, one should be able to make efficient forecasts of the target variable conditional on given values of the indicator, i.e., the indicator should be strongly exogenous. Lastly, the relationship between the indicator and the target variable should be policy invariant, i.e., the indicator should be super exogenous.

We examine these issues using quarterly data for the U.S. covering the period from 1947.Q1 through 2008.Q1. We study the long-run relationship between the *levels* of two alternative measures of prices, the CPI and Personal Consumption Expenditure Deflator (PCED), and two different measures of wages, unit labor costs (ULC) and average hourly earnings per unit of output (AHE).[2] We also investigate the short-run dynamics of the relationship between the *price inflation and wage growth*.

Our findings indicate that there is a stable, long-run relationship between each of the two measures of prices used in this study and each of the two measures of wages. Moreover, ULC is weakly exogenous for the two price

[2] Due to data availability issues, the sample period for average hourly earnings is 1964.1–2007.4.

indices suggesting that prices adjust to movements of ULC in the long run, a result that is consistent with the markup pricing hypothesis. On the hand, we find both price indices to be weakly exogenous for AHE suggesting that AHE is not a good indicator of long-run movement of prices. We also find that CPI does not Granger cause ULC at conventional levels of significance, which together with weak exogeneity of ULC implies that ULC is strongly exogenous, a result that does not hold true for Personal Consumption Expenditure Deflator. Finally, we find that ULC is super exogenous for both CPI and Personal Consumption Expenditure Deflator. Thus the general conclusion of this study is that ULC is a reliable indicator of price inflation but productivity-adjusted hourly earnings is not.

The remainder of the paper is organized as follows. Section 2 describes the empirical models and tests used in this study. Section 3 introduces the data. Section 4 presents and discusses the results. The paper closes with section 5, which summarizes this work.

2. The Relationship between Prices and Wages

Following Gordon (1988), we specify the following price and wage equations:[3]

$$\Delta p_t = \alpha_0 + \sum_{s=1}^{k} \alpha_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \alpha_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \alpha_{3s} X_t + \sum_{s=1}^{k} \alpha_{4s} Z_t + e_t^p \qquad (1)$$

$$\Delta w_t = \beta_0 + \sum_{s=1}^{k} \beta_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \beta_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \beta_{3s} X_t + \sum_{s=1}^{k} \beta_{4s} Z_t + e_t^w \qquad (2)$$

[3] These correspond to Equations (5) and (6) of Gordon (1988, p. 278).

Here, *p* is the natural logarithm of the price level, *w* is the natural log of the productivity-adjusted wage rate, *X* is excess aggregate demand, *Z* is a supply-shock variable, and e^p and e^w are random error terms corresponding to the price and wage equations, respectively.

Equations 1 and 2 constitute a two-equation non-structural vector autoregressive (VAR) system that can be used to study the short-run dynamics of the relation between price inflation and wage growth. However, as is well known, if prices and wages happen to share a common stochastic trend, that is if they are cointegrated, then the above system would have to be modified so as to incorporate this long-run information that is removed from the data when the data entering Equations 1 and 2 are differenced. The result would be a vector error-correction (VEC) model, which could take either of two forms. One approach is to retrieve the long-run information in the data by including the lagged levels of the price and wage variables, p_{t-1} and w_{t-1}, in Equations 1 and 2 in which case one would obtain the following *unrestricted* VEC model:

$$\Delta p_t = \alpha_0 + \sum_{s=1}^{k} \alpha_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \alpha_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \alpha_{3s} X_t + \sum_{s=1}^{k} \alpha_{4s} Z_t + \gamma_1 p_{t-1} + \gamma_2 w_{t-1} + e_t^p \qquad (3)$$

$$\Delta w_t = \beta_0 + \sum_{s=1}^{k} \beta_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \beta_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \beta_{3s} X_t + \sum_{s=1}^{k} \beta_{4s} Z_t + \delta_1 p_{t-1} + \delta_2 w_{t-1} + e_t^w \qquad (4)$$

Alternatively, suppose Equation 5 below represents the long-run (cointegrating) relation between wages and prices:[4, 5]

$$p_t = \mu_0 + \mu_1 w_t + u_t \tag{5}$$

Cointegration between p_t and w_t means that while these variables may be nonstationary, their linear combination, $u_t = -\mu_0 - \mu_1 w_t + p_t$ is stationary.[6] In that case, one can include u_{t-1} as the error-correction term in the system of Equations 1 and 2 its into the following *restricted* VEC model:

$$\Delta p_t = \alpha_0 + \sum_{s=1}^{k} \alpha_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \alpha_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \alpha_{3s} X_t + \sum_{s=1}^{k} \alpha_{4s} Z_t + \varphi u_{t-1} + e_t^p \tag{6}$$

$$\Delta w_t = \beta_0 + \sum_{s=1}^{k} \beta_{1s} \Delta p_{t-s} + \sum_{s=1}^{k} \beta_{2s} \Delta w_{t-s} + \sum_{s=1}^{k} \beta_{3s} X_t + \sum_{s=1}^{k} \beta_{4s} Z_t + \psi u_{t-1} + e_t^w \tag{7}$$

The restricted VEC model is useful for performing certain tests whereas the unrestricted model is preferable for other tests. These tests are described next.

A number of cointegrations tests are available for investigating the long-run relationship between prices and wages. In this study, we use two alternative OLS-based, single-equation tests due to Pesaran, Shin, and Smith (2001) and

---

[4] It should be noted that one may include a deterministic trend, dummy variables for regime changes, as well as predetermined and/or exogenous variables in Equation 5.

[5] As noted by Gordon (1988) and Mehra (2000), Equation 5 essentially reflects mark-up pricing practice by firms consistent with the basic Phillips–curve relation.

[6] Note that Equation 5 can be normalized on the wage rate to get, $w_t = -\frac{\mu_0}{\mu_1} + \frac{1}{\mu_1} p_t - \frac{1}{\mu_1} u_t$.

Stock and Watson (1993), respectively. The Pesaran-Shin-Smith bounds test for a level relationship, hereto referred to as the PSS test, is a test of joint significance of the estimated coefficients on the lagged-levels of the price and wage variables in an unrestricted VEC equation. Thus one can test the null hypothesis that $\gamma_1 = \gamma_2 = 0$ in Equation 3 or equivalently $\delta_1 = \delta_2 = 0$ in Equation 4. The test statistic is a standard F-ratio except that one has to compare it with the asymptotic critical values reported in Pesaran, Shin, and Smith (2001, Tables CI(i)-CI(v), pp. 300-301) to decide whether or not to reject the null hypothesis of no cointegration.

The cointegration test suggested by Stock and Watson (1993), referred to as the SW test in the remainder of the paper, is based on what is known as the Dynamic OLS (DOLS) regression, an equation that specifies the log of the variable of interest, say CPI, as a function of the log of the wage rate as well as the contemporaneous, leads, and lags of the log-difference of the wage rate:

$$p_t = \eta_0 + \eta_1 w_t + \sum_{s=-k}^{k} \lambda_s \Delta w_{t-s} + e_t \tag{8}$$

The Stock-Watson cointegration test is a test of statistical significance of the coefficient on the log-level of wage rate, η_1, in Equation 8. This hypothesis can be tested using the Wald test or a t-test based on standard errors that are corrected for long-run variance and that are robust to serial correlation.[7]

---

[7] See Hamilton (1994, pp. 608-612).

While cointegration implies causality in at least one direction, cointegration tests do not determine the direction in which causality flows. This can be ascertained by testing for weak exogeneity for which we use two different tests. The first test, which is due to Engle, Hendry, and Richard (1983) is performed using a restricted VEC model similar to that in Equations 6 and 7. It requires testing the statistical significance of the estimated coefficient on the error-correction term in these equations, φ in Equation 6 and Ψ in Equation 7, respectively.

Wages would be weakly exogenous for the long-run parameter in the price equation if the estimated coefficient on u_{t-1} in the equation for wage growth is not statistically significant, i.e., if $\Psi = 0$. This would mean that prices adjust to changes in wages. On the other hand, prices would be weakly exogenous if the coefficient of the error-correction term in the price equation, φ, is not statistically significant indicating that wages adjust to movements in prices.

Our second test of weak exogeneity is due to Engle (1984) who proposes examining the correlation coefficient between the error term of the conditional density function of p_t (that is u_t in Equation 5) and that of the marginal density of w_t. A small correlation coefficient between the two error terms would indicate that wages are weakly exogenous. To perform this test, one would have to estimate the marginal density of wages.[8] More on this in Section 4.

[8] The marginal density function of wages is also useful for testing for super exogeneity described below.

Weak exogeneity of wages would validate estimation of and inference on prices conditional on given values of wages. But this alone does not guarantee that we can make efficient forecasts of prices conditional upon wages, which requires another condition in addition to weak exogeneity namely that wage growth is not Granger caused by price inflation. Taken together, these two conditions result in strong exogeneity.

Granger non-causality between price inflation and wage growth can be tested using the unrestricted VEC model represented by Equations 3 and 4. Prices would not Granger cause wages if in the equation for the log-difference of wages (Equation 4) the estimated coefficients on log-differences of the price variable and that on the lagged log-level of that variable are not jointly significant that is if one cannot reject the null that $\beta_{11} = \beta_{12} = \ldots = \beta_{1k} = \delta_1 = 0$. Wages would not Granger cause prices if in the equation for the log-difference of price (Equation 3) the estimated coefficients on log-differences of the wage variable and that on the lagged log-level of wages are not jointly significant that is if $\alpha_{21} = \alpha_{22} = \ldots = \alpha_{2k} = \gamma_2 = 0$.

It was mentioned earlier that one of the issues concerning the price-wage relation is its stability over time. Emery and Chang (1996), Hess (1999), and Mehra (2000) among others have found that while over a long span of time the relationship appears to be stable, in certain sub-periods it breaks down. For example, Mehra (2000) found that “[w]age growth no longer helps predict inflation if we consider sub-periods that begin in 1980s [namely 1984.Q1-1999.Q2]…[as well as] another sub-period, 1953Q1 to 1965Q4".

A potential problem with splitting the sample into sub-samples to test for structural stability is that the resulting sub- periods may end up covering short time intervals.[9] This makes testing for cointegration and using the VEC model problematic as cointegration tests notoriously have a low power requiring long spans of time. In fact, using a short sample period but high-frequency data so as to ensure a large number of observations would not be sufficient to improve the power of these tests (Hakkio and Rush, 1991). Testing for super exogeneity is an alternative approach to testing for structural stability while avoiding the problems that might arise from splitting the sample.

Super exogeneity is a test of invariance of parameter estimates to regime changes. As such, it may be considered a test of the "Lucas critique". This is especially important in the present context as we are concerned with whether or not certain labor-market indicators can be used to help formulate monetary policy. If the parameter of interest in the long-run relationship between prices, a target variable, and wages, an indicator, is not invariant with respect to policy actions, then such a relation would not be a good guide for policy making.

Super exogeneity requires the variable under consideration to be both weakly exogenous and structurally stable. We use two alternative procedures for

[9] Mehra's sub-periods are 13 and 16 years, respectively, compared to his full sample that is more than 47 years long.

testing structural invariance of parameters of the relation between prices and wages. The first test is due to Charemza and Kiraly (1990) in which one regresses the forecast error of the conditional equation of prices on the log-difference of the variable that is being tested for super exogeneity (wages) and its lagged values. The null of super exogeneity would not be rejected if the estimated coefficients on the regressors are not jointly statistically significant.

The second test of super exogeneity used in this study is suggested by Engle and Hendry (1993) where one includes squared residuals and their lagged values from the marginal density function in the conditional density function. As with the Charemza-Kiraly test, the null of super exogeneity is not rejected if the estimated coefficients on the regressors are not jointly statistically significant.

3. Data

There are four sets of variables that are to be quantified for the empirical execution of this study. They are prices, productivity-adjusted wages, excess aggregate demand, and supply shocks. For prices, we use two different indices: the CPI and the Personal Consumption Expenditures Deflator (PCED). The reason for using the latter is the well-known problems with the use of fixed weights in constructing the CPI and also the fact that the Fed pays close attention to the PCED. The CPI data are from the BLS and those for the PCED are from the BEA.

We also use two alternative measures of wages. One is unit labor cost (ULC) representing compensation of employees, which is the sum of wages and salaries and employer's cost of employee benefits, per unit of output. ULC is essentially the employment cost index that is adjusted for productivity. Our second measure of wages is average hourly earnings in the private industry, which we adjust for changes in productivity in terms of output per hour. The result is average hourly earnings per unit of output, which we denote as AHE. The main difference between AHE and ULC is that the latter includes employees' benefits but the former does not. Both wage variables and the productivity series come from the BLS.

Following Mehra (2000), we use the ratio of potential real GDP (from the St. Louis Fed) to actual real GDP (from the BEA) as our measure of excess aggregate demand. We also follow Mehra and use the relative price of energy, which is the ratio of the PPI for fuel, related products and power to the PPI for all commodities as our supply-shock variable. Both PPI series are from the BLS.

4. Results[10]

4.a) Unit Root and Stationarity Tests

We begin with unit root tests for which we use the Augmented Dickey-Fuller and the Philips-Perron tests. The results, which are reported in Table 1, indicate that the null of unit root cannot be rejected in favor of the alternative of stationarity for any of the variables in the log-level form except for the demand-pressure variable. On the other hand, the null of unit root can be rejected at the

[10] In performing the tests reported in this section, the author benefitted from a number of papers dealing directly with the topic with which this study is concerned. The author also benefitted from several papers that are not directly related to the topic in hand including those by Sachsida (1999), Kwok and Kwok (1995), and Das and Mandal (2000).

1% level for the log-difference of the variables that contain a unit root in the log-level form.

Given the low power of unit root tests, we test the variables for stationarity using the test developed by Kwiatkowski, Phillips, Schmidt and Shin (1992). The results, which are reported in Table 2, show that the null of stationarity can be rejected in favor of the alternative of unit root for the logarithms of all series except the demand-pressure variable. The results also indicate that all non-stationary variables achieve staionarity once they are expressed in the first-difference form.

Based on these three sets of results, we conclude that, except for the demand-pressure variable, all variables are I(1) and proceed to testing for cointegration between each of the two price indices and each of the two wage variables.

4.b) Cointegration Tests

As was indicated in Section 2, we test for cointegration using two alternative single-equation, OLS-based tests, the Pesaran-Shin- Smith and the Stock-Watson tests. A number of facts about the manner in which we perform these tests should be pointed out. First, when performing both tests we control for demand pressure and supply shocks. Second, following Mehra (1993, 2000), we include a dummy variable to control for Nixon price controls in the 1971.3-1974-1 period and another for the period following the controls, from 1974.2 to 1974.4. Third, because the price and wage variables are trended, we control for the deterministic trend in each series. Fourth, time plots of the four price and wage variables reveal a break in the four series in early 1980's.[11] This coincides with the end of the money growth targeting regime in November of 1982, which was initiated by the Fed in October of 1979. In order to control for this break, we include a dummy variable that is zero prior to the fourth quarter of 1982 and is equal to one thereafter. Finally, we choose the lag lengths so as to minimize the Schwarz Information Criterion (SIC), which turns out to be 8 quarters for both the PSS and SW tests.

The long-run portions of the unrestricted VEC equations for the log-difference of CPI and PCED based on models using ULC and AHE are reported in panels A and B of Table 3, respectively.[12] In both price equations in panel A the estimated coefficient on the once-lagged value of the log of the corresponding price index has the expected negative sign and is statistically significant indicating that short-run departures from the steady-state path are eliminated in the long run. The results in panel B of Table 3 indicate that this is also true when productivity-adjusted average hourly earnings, AHE, is used as a measure of labor-market tightness.

In panel A of Table 3, the PSS cointregration test requires testing the joint significance of the estimated coefficients associated with Log(ULC)_{t-1} and

[11] Another break also appears in the ULC and AHE series beginning in the second quarter of 1960 and lasting through the second quarter of 1965. We do not control for this apparent break because when tested, it turned out to be statistically insignificant.

[12] The short-run dynamics, which include lagged log-differences and the two Nixon dummy variables and the dummy 82.4 variable are not reported but are available upon request.

Log(CPI)_{t-1} in the Δlog(CPI) equation, and those associated with Log(ULC)_{t-1} and Log(PCED)_{t-1} in the Δlog(PCED) equation. Similarly, in panel B, we test for joint significance of the corresponding coefficients on the lag-level of the price index and productivity-adjusted hourly earnings. The F-statistics for these tests are reported in Table 4.

The F-statistics for the two price equations that use ULC equal 29.29 and 16.87, respectively, both of which are much larger than the 1% upper I(1) critical value of the PSS test, which equals 5.85. This leads us to conclude that both pairs of estimates are jointly significant so that the CPI and ULC are cointegrated. The F-statistics for the ΔCPI and ΔPCED equations using adjusted average hourly earnings equal 5.37 and 4.87, respectively. These are also statistically significant, albeit at the 5% level of the SPP critical values. Hence each of the two price indices is cointergrated with each of the two wage variables.

We now turn to the Stock-Watson cointegration test. The long-run component of the estimated DOLS equations for log(CPI) and log(PCED) using ULC and AHE are reported in panels A and B of Table 5, respectively.[13] The t-statistics associated with the estimated coefficients on log(ULC) in the Log(CPI) and Log(PCED) equations in panel A of this table are 10.92 and 15.67,

[13] Once again, the short-run dynamics, which include lagged log-differences the two Nixon era price and wage control dummy variables, and the dummy variable for the break in the data in 1982.4 are not reported to conserve but are available from the author.

respectively.[14] These have p-values that are nearly zero leading us to reject the null of no cointegration. Note that the estimated coefficient on ULC in the CPI equation, which equals 1.20, is statistically different from 1 at the 5% level (t = 1.82). Thus it appears that in the long run there is a 20% price markup over average labor cost in the non-farm business sector. But in the PCED equation, the estimated coefficient on Log(ULC), which equals 1.05, is not statistically different from 1 (t = 0.75) suggesting that in the long run there is a one-for-one relation between ULC and PCED so that the long-run markup over cost is zero. These differing results reflect the well-known facts regarding the differences in the manner in which the two price indices are measured.

Panel B of Table 5 contains the long-run results from the estimated DOLS equations for the CPI and PCED price indices using productivity-adjusted wages, AHE. The results indicate that the estimated coefficient on log(AHE) in both Log(CPI) and Log(PCED) equations is statistically significant at high levels of confidence leading us to conclude that each of the two price indices is cointegrated with the adjusted average hourly earnings. What is more, the estimated coefficient on AHE in both the CPI and PCE equations is not statistically different from one so that there is a one-for-one relationship between prices and AHE in the long run.

To summarize, using two different cointegration tests, we found that there is a stable long-run relation between each of the two different measures of

[14] Recall from the previous section that these t-statistics are based on standard errors that are adjusted for long-run variance and that are also robust to serial correlation.

consumer prices and the two different productivity-adjusted measures of labor cost of production.[15] However, we do not know whether wages help determine prices in the long run or they adjust to movement of prices. In order to answer this question we need to test for weak exogeneity to which we turn next.

4.c) Weak Exogeneity Tests

We begin with the Engle, Hendry, and Richard (1983) test using the restricted VEC model, which includes once-lagged residuals, u_{t-1}, from a regression equation with a price index (CPI or PCED) as the dependent variable and a wage variable (ULC or AHE) as the regressor. We test for weak exogeneity by testing the statistical significance of the estimated coefficient on the error-correction term in each pair of price-wage equations. Table 6 reports estimates of the coefficient on the error-correction term in each of the four price and wage equations. As these results indicate, ULC is weakly exogenous for the parameter of interest in each of the two price equations, while the two price indices are weakly exogenous for AHE.[16] Thus it appears that prices adjust to movements in ULC but AHE adjusts to changes in prices.

Consider now the test of weak exogeneity that is due to Engle (1984), which requires an examination of the correlation coefficient between the error term of the conditional density and that of the marginal density. In order to

---

[15] We also used Johansen's (1988) maximal-eigenvalue and trace tests and found results that were in conformity with those reported above.

[16] Using a variant of this test based on maximum-likelihood estimates of the long-run parameters of the four alternative price-wage equations, we obtained results that were consistent with those reported here.

perform this test, we need to specify and estimate the marginal density functions of ULC and AHE. Drawing on Marterbauer and Walterskirchen (2003) and specify the logarithm of ULC as a function of the unemployment rate, the log of gross private domestic investment, the growth rate of real GDP, the level of productivity, and the expected inflation rate. For expected inflation we use the University of Michigan's measure, which is available for the period from 1960.1 through 2007.4.[17]

Using these variables, we estimate marginal densities of ULC and AHE and use the results to find the correlation coefficients between the estimated residuals from these equations and those from the corresponding conditional equations of the two price variables. The results, which are found in Table 7, indicate that these correlation coefficients are small and not statistically significantly different from zero. On the other hand, the error correlation coefficients corresponding to AHE and the two price variables, while not quite large, are statistically significantly different from zero. These results are in conformity with our earlier finding that ULC is weakly exogenous for the long-run parameter of both price equations, but AHE is not.[18]

[17] The estimated marginal distributions are not reported but are available from the author.

[18] We also tested for weak exgeneity using a slightly different version of the Engle test where we included the residuals and squared residuals form the marginal distribution of wages in the conditional distribution of prices. Wages would be weakly exogenous for prices if the estimated coefficients on these terms are not jointly statistically significant. Performing this test, we found evidence of weak exogeneity of ULC but not AHE, results that are consistent with those reported above.

4.d) Strong Exogeneity Tests

Because AHE is not weakly exogenous, it cannot be strongly exogenous, which requires both weak exogeneity and Granger non-causality of wages. Thus our strong exogenity test is limited to ULC. We test for Granger causality between each of the two price indices and ULC using the unrestricted VEC model we used earlier for the PSS test of cointegration (see Table 4). Prices would not Granger cause ULC if in the equation for the log-difference of ULC the estimated coefficients on log-differences of the price variable and that on the lagged log-level of that variable are jointly insignificant. The Granger causality tests results are found in Table 8. They indicate that there is a one-way causality in the Granger sense from ULC to CPI albeit at a relatively low level of confidence (p-value equals 12.5%). The results are weaker for the PCED as the hypothesis that it does not Granger-cause ULC can actually be rejected at slightly better than the 10% level (p-value equals 8%).

4.e) Super Exogeneity Tests

As was indicated earlier, we test the stability of the relationship between prices and wages using two different tests of super exogeneity. One is due to Charemza and Kiraly (1990), which requires regressing the forecast error of the conditional density of prices on the log-difference of wages. The second test is suggested by Engle and Hendry (1993) where one includes squared residuals and their lagged values from the marginal density of wages in the conditional density of prices. In each case, the null of super exogeneity would not be rejected if the estimated coefficients on the regressors are not jointly statistically significant. For both tests, we use the same specification for the marginal equation as that we used earlier to perform Engle's test of weak exogeneity. The results of both Charemza-Kiraly and Engle-Hendry tests, which are reported in Table 9, suggest that ULC is super exogenous for both price indices.

5. Summary

In this study we examined two different measures of wages as predicators of prices in a vector error-correction framework using quarterly data for the U.S. for the period from 1947.Q1 through 2008.Q1 to perform a series of exogeneity tests. Our findings are summarized as follows:

a. *There is a stable, long-run relationship between the CPI and the Personal Consumption Expenditure Deflator (PCED) on the one hand and unit labor costs (ULC) and average earnings per unit of output (AEH) on the other.*

This is consistent with the results reported by many researchers when considering long spans of time (e.g., Ghali 1999; Hess and Schweitze 2000; Huh and Trehan 1995; Mehra 1993, 2000).

b. *ULC is weakly exogenous for both price indices suggesting that prices adjust to movements of ULC in the long run and not the other way around, a result that is consistent with markup pricing hypothesis. On the hand, both price indices are weakly exogenous for AHE suggesting that AHE is not a good indicator of long-run movement of prices.*

We can explain the finding that ULC is weakly exogenous but AHE is not in terms of the behavior of employee's benefits, which is included in the former but not the latter.[19] It follows from the above results that benefits must be weakly exogenous. Indeed, this is what we found when we tested benefits against the two price indices for the period from 1982.1 through 2007.3 for which benefit data are available.

c. *CPI does not Granger cause ULC at conventional levels of significance. This, coupled with the finding that ULC is weakly exogenopus implies that ULC is strongly exogenous and thus can be used to obtain efficient forecasts of CPI. This result does not hold true for Personal Consumption Expenditure Deflator.*

The result that ULC is weakly exogenous for CPI is consistent with Mehra's (2000) full-sample (1952.1-1999.2) finding but contradicts Gordon's (1988, p. 276) conclusion that "the markup pricing hypothesis is dead".

d. *ULC is super exogenous for CPI indicating that the relationship between them is structurally stable.*

This is different from findings by those who split the sample period and perform all tests and estimations over sub-periods (e.g., Hess and Schweitzer 2000 and Mehra 2000).

Taken together, these findings lead us to conclude that ULC is a reliable indicator of price inflation but productivity-adjusted hourly earnings is not. Thus monetary policy makers are justified in using information about the behavior of ULC in formulating policy actions for achieving the goal of price stability.

[19] ULC is the sum of compensation and benefits per unit of output while productivity-adjusted AHE represents compensations per unit of output only.

References

Charemza, Wojciech and Julia Király (1990) “Plans and Exogeneity: The Genetic-Technological Dispute Revisited,” *Oxford Economic Papers*, 42, 562-73.

Clark, Todd E. (1997) “Do Producer Prices Help Predict Consumer Prices,” Federal Reserve Bank of Kansas City Research Paper No. 97-09.

Das, Samarjit and Kumarjit Mandal (2000) “Modeling Money Demand in India: Testing Wek, Strong, and Super Exogeneity,” *Indian Economic Review*, 35, 1-19.

Engle, Robert F., Hendry, David F. and Jean-Francois Richard (1983) “Exogeneity,” *Econometrica*, 51, 277-304.

Ghali, Khalifa (1999) “Wage Growth and the Inflation Procss: A Multivariate Cointegration Analysis,” *Journal of Money, Credit and Banking*, 31, 417-431.

Gordon, Robert J. (1998) “The Role of Wages in the Inflation process,” *American Economic Review*, 78, 276-283.

Hakkio, Craig S. and Mark Rush (1991) "Cointegration: How Short is the Long Run?" *Journal of International Money and Finance*, 10, 571-81.

Hamilton, James D. (1994) *Time Series Analysis*, Princeton University Press.

Hess, Gregory D. and Mark E. Schweitzer (2000) “Does Wage Inflation Cause Price Inflation?” Federal Reserve Bank of Cleveland Policy Discussion Paper No. 1

Huh, Chan G. and Bharat Trehan (1995) “Modeling the Time Series Behavior of the Aggregate Wage Rate,” Fedearl Reserve Bank of San Francisco *Economic Review*, 1, 3-13.

Kwiatkowski, Dennis., Phillips, Peter .C.B. Schmidt, Peter and Yongcheol Shin (1992), ”Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root”, *Journal of Econometrics*, 54, 159-178.

Kwan, Andy C.C. and Benjamin Kwok (1995) “Exogeneity and the Export-led Growth Hypothesis: The Case of China,” *Southern Economic Journal*, 61, 1158-1166.

Marterbauer, Markus and Ewald Walterskirchen (2003) “Determinants of Wage Share and Real Unit Labor Costs,” Austrian Institute of Economic Research *Monthly Reports*, 76, 151-159.

Mehra, Yash (2000) “Wage-Price Dynamics: Are they Consistent with Cost Push?” Federal Reserve Bank of Richmond *Economic Quarterly*, 86, 27-43.

Mehra, Yash (1993) “Unit Labor Cost and the Price Level,” Federal Reserve Bank of Richmond *Economic Quarterly*, 74, pp. 35-51.

Rissman, E.R. (1995) “Sectoral Wage Growth and Inflation,” Federal Reserve Bank of Chicago *Economic Review*, pp. 16-28.

Sachsida, Adolfo (1999) ”Testes de Exogeneidade sobre a Correlação Poupança Doméstica e Investimento,” Institute for Applied Economic Research Discussion Paper No. 659, Catholic University of Brasilia. An English version of this paper titled, "Domestic Saving and Investment: Exogeneity Tests" (undated) is available at http://ssrn.com/abstract=218755.

Stock, James H. and Mark W. Watson (1993) “A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems,” *Econometrica*, 61, 783-820.

Table 1
Unit Root Tests[a]

A. Augmented Dickey-Fuller Tests (Lag Lengths in Parentheses)[b]

	First Difference[c]	p-value		Level[d]	p-value
Log(CPI)	-4.056 (3)	0.00		-1.38 (4)	0.86
LOG(PCED)	-3.36 (2)	0.01		-1.46 (3)	0.84
Log(ULC)	-6.81 (1)	0.00		-0.76 (2)	0.97
Log(AHE)	-11.97 (0)	0.00		-0.35 (0)	0.99
Log(Demand Pressure)[e]	---	---		-4.21 (1)	0.00
Log(Supply Shock)[f]	-7.66 (3)	0.00		-2.23 (3)	0.47

B. Phillips-Perron Tests (Bandwidths in Parentheses)[g]

	First Difference[c]	p-value		Level[d]	p-value
Log(CPI)	-5.26 (5)	0.00		-1.57 (11)	0.80
Log(PCEDD)	-5.30 (6)	0.00		-1.31 (11)	0.88
Log(ULC)	-12.20 (9)	0.00		-1.00 (9)	0.94
Log(AHE)	-12.22 (6)	0.00		-0.61 (6)	0.98
Log(Demand Pressure)[e]	---	---		-3.62 (2)	0.01
Log(Supply Shock)[f]	-11.05 (0)	0.00		-1.92 (3)	0.64

a. All series are for 1947.1-2008,1 except AHE, which is for 1964.1-2008.1.
b. Choice of lag lengths is based on minimum SIC starting with a maximum lag of 12 quarters.
c. Test equations include an intercept but no linear trend.
d. Test equations include an intercept and a linear trend except that of demand pressure that includes only an intercept.
e. Log of the ratio of actual real GDP to potential real GDP.
f. Log of the ratio of the PPI for fuel, related products and power to the overall PPI.
g. Choice of lag lengths is based on bandwidths based on the Newey-West nonparametric method using Bartlett kernel.

Table 2
Kwiatkowski-Phillips-Schmidt-Shin Stationarity Tests[a]
(Bandwidths in Parentheses)[b]

	First Difference[c]		Level[d]
Log(CPI)	0.32 (11)		0.25** (11)
Log(PCED)	0.33 (11)		0.25** (11)
LOG(ULC)	0.28 (9)		0.25** (11)
LOG(AHE)	0.41 (6)*		0.38** (10)
Log(Demand Pressure)[e]	---		0.31 (11)
Log(Supply Shock)[f]	0.14 (3)		0.14* (11)

a. All series are for 1947.1-2008,1 except AHE, which is for 1964.1-2008.1.
b. Choice of lag lengths is based on bandwidths based on the Newey-West nonparametric method using Bartlett kernel.
c. Test equations include an intercept but no linear trend.
d. Test equations include an intercept and a linear trend except that of demand pressure that includes only an intercept.
e. Log of the ratio of actual real GDP to potential real GDP.
f. Log of the ratio of the PPI for fuel, related products and power to the overall PPI.

Table 3
Estimated Long-run Components of Unrestricted VEC Models
Absolute Value of t-Ratios in Parentheses)

A. ULC

Equation	Intercept	$Log(ULC)_{t-1}$	$Log(CPI)_{t-1}$	$Log(PCED)_{t-1}$
$\Delta Log(CPI)_t$	-0.047 (7.48)*	0.047 (5.26)*	-0.031 (4.34)*	
$\Delta Log(PCED)_t$	-0.037 (5.35)*	0.040 (3.88)*		-0.032 (3.37)*

B. AHE

Equation	Intercept	$Log(AHE)_{t-1}$	$Log(CPI)_{t-1}$	$Log(PCED)_{t-1}$
$\Delta Log(CPI)_t$	0.155 (4.02)*	0.031 (4.00)*	-0.015 (-3.83)*	
$\Delta Log(PCED)_t$	0.090 (2.56)*	0.017 (2.47)*		-0.011 (2.54)*

*Significant at the 1% level.
** Significant at the 5% level.

Table 4

Pesaran-Shin-Smith Cointegration Tests

F-Statistics for Testing Joint Significance of Lag-Levels in Unrestricted VEC Price Equations

Equation	Lagged-Levels	F-Statistic
$\Delta Log(CPI)_t$	$Log(CPI)_{t-1}$ & $Log(ULC)_{t-1}$	29.29*
$\Delta Log(PCED)_t$	$Log(PCED)_{t-1}$ & $Log(ULC)_t$	16.87*
$\Delta Log(CPI)_t$	$Log(CPI)_{t-1}$ & $Log(AHE)_{t-1}$	5.37**
$\Delta Log(PCED)_t$	$Log(PCED)_{t-1}$ & $Log(AHE)_{t-1}$	4.87**

* Significant at the 1% level using the critical values in Table CI(iv) in Pesaran *et al.* (2001).

** Significant at the 5% level using the critical values in Table CI(iv) in Pesaran *et al.* (2001).

Table 5

Estimated Long-run Components of DOLS Models

(Numbers in Parentheses are Absolute Values of t-Ratios)[a]

A. ULC

Equation	Intercept	$Log(ULC)_t$	Trend
$Log(CPI)_t$	-0.54 (0.65)	1.20 (10.92)*	-0.00 (0.05)
$Log(PCED)_t$	-0.45 (2.23)**	1.05 (15.67)*	0.00 (0.4)

B. AHE

Equation	Intercept	$Log(AHE)_t$	Trend
$Log(CPI)_t$	6.55 (18.01)*	1.08 (10.79)*	0.004 (6.04)*
$Log(PCED)_t$	6.16 (16.08)*	1.04 (9.92)*	0.003 (4.05)*

[a]Based on standard errors that are adjusted for long-run variance.

*Significant at the 1% level.

Table 6

Engle-Hendy-Richard Test of Weak Exogeneity

Tests of Significance of the Coefficient on Error-Correction Term in Restricted VEC Models (t-Ratios in Parentheses)

Equation	u_{t-1}
$\Delta Log(CPI)_t$	-0.030 (3.86)*
$\Delta Log(ULC)_t$	0.003 (0.19)
$\Delta Log(PCED)_t$	-0.033 (3.29)*
$\Delta Log(ULC)_t$	0.006 (0.23)
$\Delta Log(CPI)_t$	-0.019 (1.00)
$\Delta Log(AHE)_t$	0.077 (2.29)**
$\Delta Log(PCED)_t$	-0.002 (0.20)
$\Delta Log(AHE)_t$	0.076 (2.62)*

* Significant at the 1% level.
** Significant at the 5% level.

Table 7
Engle Test of Weak Exogeneity
Correlation Coefficient between the Residuals from Marginal Equations of Wages and Residuals from Conditional Equations of Prices
(t-Ratios in Parentheses)

Marginal Distribution / Conditional Distribution	$Log(ULC)_t$	$Log(AHE)_t$
$Log(CPI)_t$	0.04 (0.55)	0.14 (1.86)*
$Log(PCED)_t$	0.07 (0.97)	0.19 (2.55)**

* Significant at the 10% level.
** Significant at the 5% level.

Table 8
Granger Causality Tests

Hypothesis	p-Value*
CPI does not Granger cause ULC	0.125
ULC does not Granger cause CPI	0.000
PCED does not Granger cause ULC	0.080
ULC does not Granger cause PCED	0.001

* The p-values are for the F-test of joint significance of log-differences and log-level in the unrestricted VEC models.

Table 9
F-Tests of Super Exogeneity of ULC
(p-Values in Parentheses)

	Charemza-Kiraly Test (1949.1 2008.1)	Engle-Hendry Test (1960.1 2007.4)
CPI	1.17 (0.31)	0.55 (0.83)
PCED	1.03 (0.42)	0.32 (0.96)